

Exhibit 57

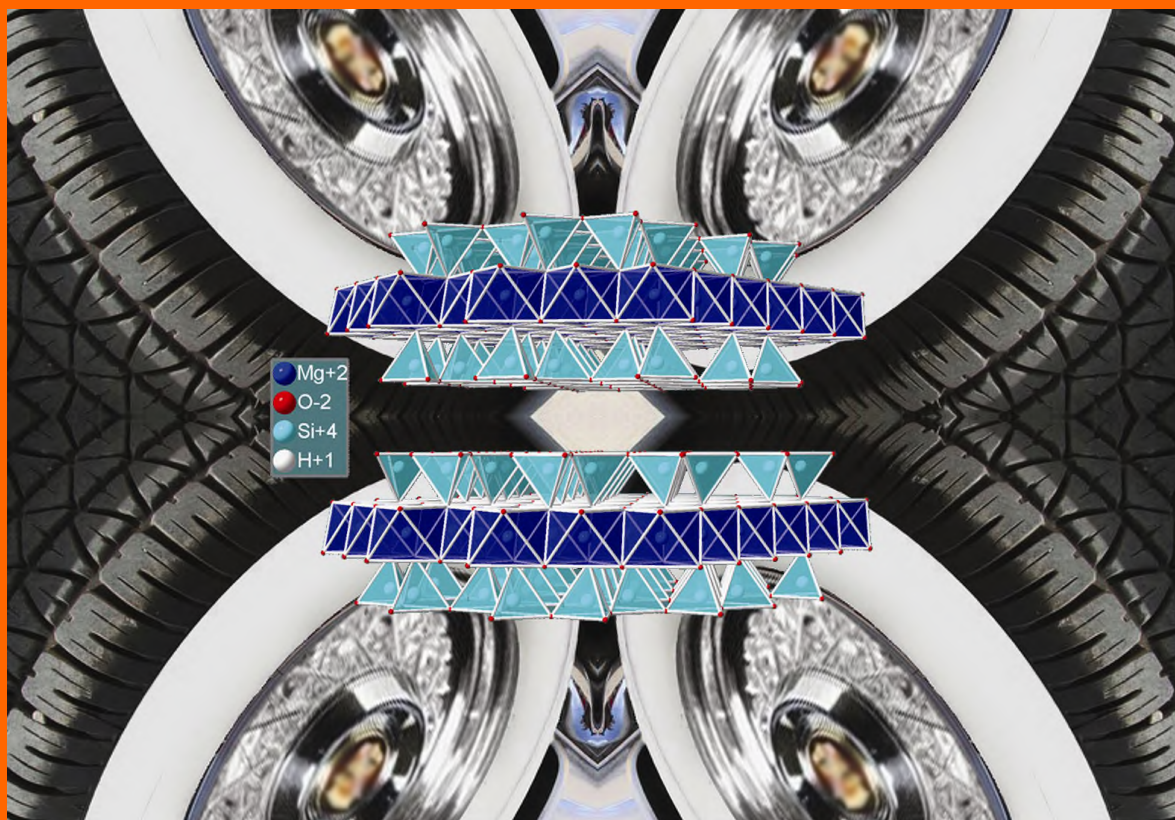
WORLD HEALTH ORGANIZATION
INTERNATIONAL AGENCY FOR RESEARCH ON CANCER



IARC Monographs on the Evaluation of Carcinogenic Risks to Humans

VOLUME 93

Carbon Black, Titanium Dioxide, and Talc



LYON, FRANCE
2010

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This publication represents the views and expert opinions
of an IARC Working Group on the
Evaluation of Carcinogenic Risks to Humans,
which met in Lyon,

7–14 February 2006

2010

IARC MONOGRAPHS

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This programme has been supported since 1982 by Cooperative Agreement U01 CA33193 with the United States National Cancer Institute, Department of Health and Human Services. Additional support has been provided since 1986 by the Health, Safety and Hygiene at Work Unit of the European Commission Directorate-General for Employment, Social Affairs and Equal Opportunities, and since 1992 by the United States National Institute of Environmental Health Sciences, Department of Health and Human Services. The contents of this volume are solely the responsibility of the Working Group and do not necessarily represent the official views of the U.S. National Cancer Institute, the U.S. National Institute of Environmental Health Sciences, the U.S. Department of Health and Human Services, or the European Commission Directorate-General for Employment, Social Affairs and Equal Opportunities.

This volume was made possible, in part, through Cooperative Agreement CR 834012 with the United States Environmental Protection Agency, Office of Research and Development. The contents of this volume do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

Published by the International Agency for Research on Cancer,
150 cours Albert Thomas, 69372 Lyon Cedex 08, France
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Distributed by WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland
(tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int).

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IARC Library Cataloguing in Publication Data

Carbon black, titanium dioxide, and talc / IARC Working Group on the Evaluation of Carcinogenic Risks to Humans (2006: Lyon, France)

(IARC monographs on the evaluation of carcinogenic risks to humans; v. 93)

1. Carcinogens, Environmental 2. Inhalation Exposure – adverse effects 3. Lung Neoplasms – chemically induced 4. Soot – toxicity 5. Talc – toxicity 6. Titanium – toxicity

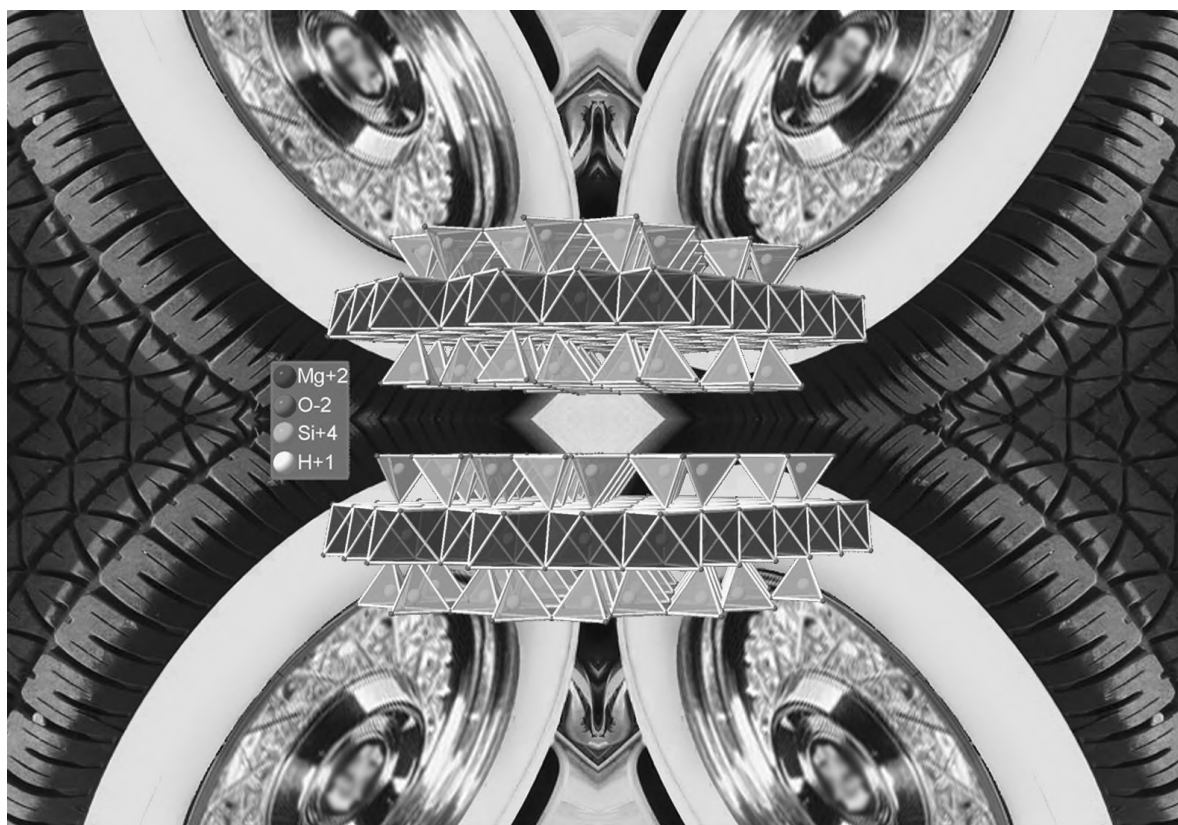
I. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans II. Series

ISBN 978 92 832 1293 5

(NLM Classification: W1)

ISSN 1017-1606

PRINTED IN FRANCE



Cover photograph: The white-wall automobile tyre represents carbon black and titanium dioxide; the chemical structure illustrates the platy structure of talc (see Section 1 for details).

Cover photograph and design: Roland Dray, IARC

Source of the talc structure: <http://en.wikipedia.org/wiki/File:Talc.GIF>

TALC NOT CONTAINING ASBESTIFORM FIBRES

1. Exposure Data

Introduction

Talc refers to both mineral talc and industrial mineral products that are marketed under the name talc and contain proportions of mineral talc that range from about 35% to almost 100%.

The mineralogy of airborne particles in talc mines is restricted by that of the deposit and associated rocks. Therefore, mines and mills provide an opportunity to characterize exposure to one specific source of talc mineralogically. In contrast, the mineralogy of talc in an industrial setting where talc products are used may be difficult to characterize, because many different sources of talc are available for almost every application. Industrial talcs are quite variable in their talc content and in the identity and proportion of other minerals that they contain. In addition, talc is part of a complex mixture of materials in user industries.

Talc particles are normally plate-like. When viewed under the microscope in bulk samples or on air filters, they may appear to be fibres and have been identified as such. Talc may also form as true mineral fibres that are asbestiform; asbestiform describes the pattern of growth of a mineral that is referred to as a 'habit'. Asbestiform talc fibres are very long and thin and occur in parallel bundles that are easily separated from each other by hand pressure.

Asbestos is a commercial term that describes six minerals that occur in the asbestiform habit: actinolite, anthophyllite, chrysotile, grunerite, riebeckite and tremolite (IARC, 1977). Similarly to talc, these six minerals occur more commonly in a non-asbestiform habit, and may also be elongated without being asbestiform. Actinolite, anthophyllite and tremolite may occur in some talc deposits; when asbestiform, they constitute asbestos and, when not asbestiform, they are referred to as mineral fragments or cleavage fragments.

1.1 Chemical and physical data

1.1.1 Nomenclature

CAS Registry No.: 14807–96–6

Chem. Abstr. Name: Talc

*Synonyms*¹: Soapstone; steatite; talcum

*Trade names*¹: Trade names of industrial, cosmetic and pharmaceutical talc include Agalite, Asbestine, Australian microcrystalline, Beaver White 200, CP 10–40, CP 38–33, Crystalite CR 6002, Desertalc 57, Emtal 500, Emtal 549, Emtal 596, Emtal 599, Ex-IT, Fibrene C 400, Finntalc, French Chalk, FW-XO, HSDB 830, IT Extra, LMR 100, Microneeca K1, Micro White 5000A, Microtalco IT Extra, Mistron, Montana talc, MP 25–38, MP 40–27, MP 45–26, MST, MT 12–50, Mussolinite, NCI-CO6018, Nyltal 200, Nyltal 400, Pk-C, Pk-N, Plustalc, Polytal 4641, Polytal 4725, Snowgoose, Steawhite, Supreme, Supreme dense, Talcan PK-P, Talcron CP 44–31 and Westmin.

Rocks or mineral composites that contain talc mineral include agalite, potstone, soapstone and talcite. Soapstone generally contains at least 25% of minerals other than talc while talcite is sometimes used to describe rock that contains at least 75% talc (Harben & Kuzvart, 1996). Steatite originally referred to a rock that is relatively pure talc; today, it denotes a ceramic body with a high talc content that is used as an electrical insulator. The talc that is used in such applications is known as steatitic talc. French chalk is soft massive talc (Piniaskiewicz *et al.*, 1994). Talc has also been referred to as snowgoose, agalite and kerolite. Industrial talc generally refers to products that contain abundant minerals other than talc; cosmetic talc now normally contains >98% talc (Zazenski *et al.*, 1995) but the content may have been lower in the past (Rohl *et al.*, 1976). Pharmaceutical talc contains >99% talc. Talcum powder is cosmetic-grade talc (Zazenski *et al.*, 1995). Pyrophyllite is similar to talc in atomic structure but contains aluminium instead of magnesium ($\text{Al}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$) (Bish & Guthrie, 1993); the two minerals do not occur together in nature, although they have similar industrial applications.

1.1.2 Structure of the typical mineral

Chemical formula: $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$

Molecular weight: 379.26

The original X-ray spectra of talc (Gruner, 1934; Hendricks, 1938) indicated that mineral talc had a monoclinic structure. Later investigations (Ross *et al.*, 1968; Rayner & Brown, 1973) demonstrated that talc is triclinic (Table 1.1). The small deviations from 90° in angle α and angle γ result in the triclinic symmetry. Indexing the X-ray diffraction

¹ These synonyms and trade names cover talc, materials that contain talc and talc that is contaminated with other minerals as admixtures.

pattern as a monoclinic structure assumes that angles α and γ are each 90° and doubles the magnitude of one of the lattice parameters (parameter 'c' in Table 1.1).

Table 1.1. Lattice parameters and crystallographic axes of talc

Lattice parameters (nm)			Crystallographic axes			System	References
a	b	c	α	β	γ		
0.5255	0.9137	0.9448	$90^\circ 46'$	$98^\circ 55'$	$90^\circ 00'$	Triclinic	Ross <i>et al.</i> (1968)
0.5293	0.9179	0.9496	$90^\circ 57'$	$98^\circ 91'$	$90^\circ 03'$	Triclinic	Rayner & Brown (1973)

The structure of talc is characterized by a hexagonal sheet arrangement of silicon–oxygen tetrahedral groups linked in a common plane. Each silicon–oxygen tetrahedron shares three planar oxygen atoms with its neighbouring tetrahedra; the fourth oxygen, the apex of the tetrahedron, is not shared. Two such sheets are orientated so that unshared apical oxygen atoms face each other. The sheets are bonded by magnesium atoms that are coordinated octahedrally by two oxygen atoms from each tetrahedral sheet and two hydroxyl groups. This structural arrangement results in a double-sheet structure in which the valence demands of the constituent atoms are completely satisfied without interlayer cations; these double-sheet units are held together only by weak van der Waal's bonds. The double-sheet units are easily separated by slight forces that result in a perfect cleavage direction in the basal plane (Rohl *et al.*, 1976; Pooley & Rowlands, 1975). The structure of talc is depicted in Figure 1.1 (see cover photo of this Volume).

1.1.3 Chemical and physical properties of mineral talc

Hardness: 1 on Mohs' scale

Density: 2.58–2.83

Cleavage: (001) perfect

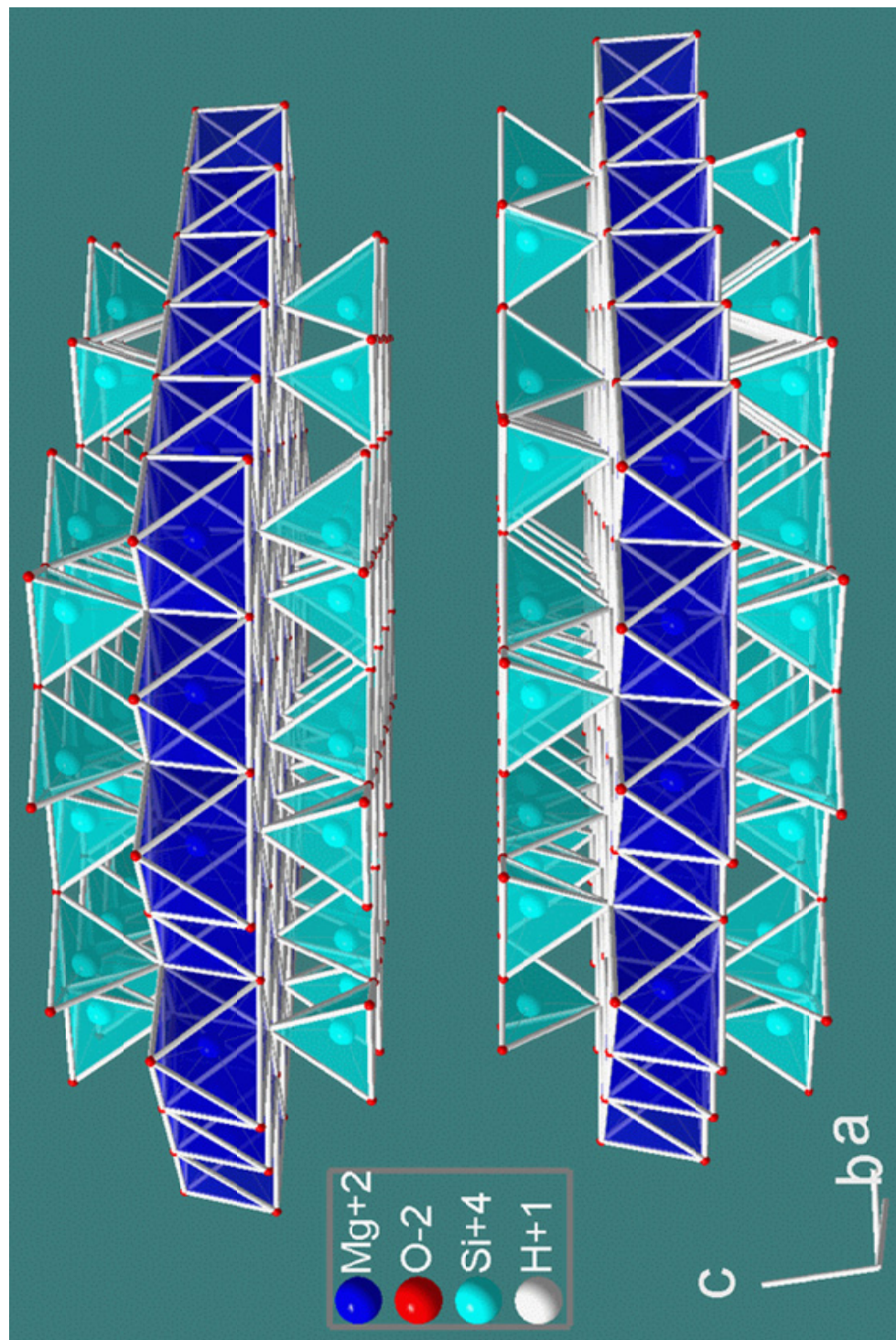
Colour: Pale to dark green or greenish grey to black; also white, silvery-white, grey, brownish

Luster: Translucent; pearly, greasy or dull

Indices of refraction: Talc is biaxial with $\alpha=1.539$ – 1.550 , $\beta=1.589$ – 1.594 and $\gamma=1.589$ – 1.600 . The indices of refraction increase with iron content. Because β and γ are approximately equal, talc appears to be uniaxial (Deer *et al.*, 1962).

Description: Commonly thin tabular crystals, up to 1 μm in width; talc is usually massive, fine-grained and compact; it also occurs as foliated or fibrous masses or in globular stellate groups. Talc particles are normally thin and plate-like, but the size of the individual plates varies among different bodies of ore. When viewed under the microscope on end, talc platelets may appear as fibres (Cralley *et al.*, 1968). These are not true fibres and should not be confused with asbestiform talc. Asbestiform talc is

Figure 1.1 Schematic structure of talc



From NIMSOoffice, <http://en.wikipedia.org/wiki/File:Talc.GIF>

formed when talc plates elongate parallel to the a axis within the plate to form true ribbon-like fibres of talc. These fibres may occur in an asbestiform habit consisting of bundles of narrow fibres randomly oriented around the axis of elongation (c axis). In some deposits, including those in the Gouverneur District of New York State, a small proportion of talc fibres are intergrown on a nanoscale with amphiboles (Stemple & Brindley, 1960; Greenwood, 1998; Wylie *et al.*, 1997).

Chemical composition: The ideal formula is $\text{Mg}_3\text{Si}_4\text{O}_{10}(\text{OH})_2$. When expressed in the standard oxide form, the ideal chemical composition is: 31.9% MgO, 63.4% SiO_2 and 4.8% H_2O (Piniakiewicz *et al.*, 1994). No talc is ideal, and small amounts of aluminium and iron are common impurities. Aluminium may substitute for both magnesium and silicon; iron(II) and iron(III) may substitute for magnesium. Talc that has almost all magnesium substituted by iron is called minnesotaite and is abundant in the iron formations of Minnesota, USA (Deer *et al.*, 1962). Fluorine is the most common substitution for the hydroxy group (Petit, 2005). Small amounts of nickel, chromium, calcium, potassium, sodium and manganese are also found in the octahedral sites while titanium may substitute for silicon in the tetrahedral site. Table 1.2 provides examples of the variability in the composition of mineral talcs, talc ores and talc products.

Solubility: The solubility of talc has been described in detail by Jurinski and Rimstidt (2001). On the sole basis of dissolution under pulmonary conditions, authors estimated that the maximum residence time in the lung of a 1- μm 'spherical' particle of talc is approximately 8 years. The reader is referred to Section 4 for a detailed description of the kinetics of deposition and clearance.

1.1.4 *Chemical and mineralogical characteristics of talc deposits*

Talc ore deposits are formed from the hydrothermal metasomatism of pre-existing rocks by fluids that contain silicon and/or magnesium. Hydrothermal fluids may be derived from fluids that migrate during retrograde or prograde regional metamorphism or from contact metamorphism that is associated with nearby or distant intrusive igneous rocks. The chemical composition of talc and its associated minerals result from the original rock type, the nature of the hydrothermal alteration and metamorphic history (Harben & Kuzvart, 1996).

The chemical and mineral compositions of talc from various locations are shown in Tables 1.2 and 1.3, respectively.

(a) *Talc derived from mafic and ultramafic rocks*

Talc deposits, the protoliths of which are ultramafic (or mafic) rocks, are abundant in number but small in total production. They are found in discontinuous bodies in orogenic belts, such as the Alps, the Appalachians and the Himalayas, and form during the regional metamorphism that accompanies orogenesis. They also occur in Canada (Ontario and Quebec), Egypt, Finland, Germany, Norway, the Russian Federation (Shabry and Miassy),

Table 1.2 Chemical composition (wt%) of selected mineral talcs, talc ores and talc mineral products

Component	Mineral talc ^{a,b}	Talc ores ^c																	
		1	2	3	4	5	6	7	8	9	1 ^d	2 ^d	3 ^d	4 ^d	5 ^e	6 ^e	7 ^e	8 ^e	9 ^f
SiO ₂	62.61	62.67	62.47	62.16	60.06	60.02	60.88	61.07	51.29	70.8	49.8	44.6	44.8	35.98	59.15	62.65	59.80	54.92	60
TiO ₂	—	—	—	—	—	—	0.10	—	0.04	0.07	0.03	0.03	0.06	0.02	—	—	—	—	—
Al ₂ O ₃	—	0.38	0.47	0.88	1.60	1.88	1.98	2.42	0.61	0.69	0.48	0.45	1.20	0.43	0.26	0.31	0.57	—	0.70
Fe ₂ O ₃	—	0.68	—	—	—	—	0.83	1.49	2.00	0.86	0.29	0.51	0.46	0.65	3.36	1.51	0.05	0.46	2.2
FeO	2.46	0.65	0.79	1.41	1.74	1.51	—	—	33.66	—	—	—	—	5.96	—	—	0.15	—	—
MnO	0.01	—	0.00	—	—	—	—	—	0.12	0.01	0.02	0.03	0.03	0.41	—	—	0.39	—	—
MgO	30.22	29.95	31.76	30.86	30.83	30.39	31.18	29.13	6.26	23.2	19.9	23.2	25.0	32.95	31.34	30.23	27.45	27.20	31
CaO	—	1.35	0.00	—	0.40	1.00	0.14	0.75	0.00	0.07	10.4	14.7	9.98	0.00	0.15	Trace	6.80	5.76	—
Na ₂ O	—	—	—	—	—	—	—	—	0.08	<0.15	<0.15	<0.15	0.59	0.00	—	0.15	—	—	—
K ₂ O	—	—	—	—	—	—	—	—	0.03	<0.02	0.31	<0.02	0.93	0.00	—	0.05	—	—	—
Loss on ignition	—	—	—	—	—	—	—	—	—	3.99	18.1	16.0	16.1	23.18	6.06	5.14	5.93	10.76	5.80
NiO	—	—	—	—	—	—	—	—	—	—	—	—	—	0.21	—	—	—	—	—
Cr ₂ O ₃	—	—	—	—	—	—	—	—	—	—	—	—	—	0.18	—	—	—	—	—
H ₂ O ⁺	4.72	5.05	4.70	4.92	5.02	5.37	4.98	4.82	5.54	—	—	—	—	—	—	—	—	—	—
H ₂ O [−]	—	—	0.06	—	—	0.32	—	—	0.24	—	—	—	—	—	—	—	—	—	—

^a From Deer *et al.* (1962)^b 1, Talc, altered peridotite (Muruhatten, northern Sweden); 2, Talc (Shabrov, Urals, USSR); 3, Talc (Murphy, NC, USA); 4, Light-green talc (Malangen, Norway); 5, Green talc, altered serpentine (Parma district, Apennines, Italy); 6, Black talc, with carbonaceous material derived from a bluish gray rock (Parma, Apennines, Italy); 7, Talc (Mount Fitton, South Australia); 8, Talc, altered tremolite (Yellandu Warangal district, Hyderabad, India); 9, Greenish gray iron talc (minnesotaite) (East Mesabi range, MN, USA)^c 1, Talc rock (Alliance Mine, CA, USA); 2, Talc ore (Pleasanton Mine, CA, USA); 3, Talc ore (Talc City, USA); 4, Talc ore (Acme Mine, CA, USA); 5, Vermont talc-magnesite ore (USA); 6, Flotation product (Johnson, VT, USA); 7, Steatite (Yellowstone Mine, MT, <USA); 8, Average ore (Talcville, NY, USA); 9, Texas talc (USA); 10, FINNTALC M30^d From Van Gosen *et al.* (2004)^e From Chidester *et al.* (1964)^f From Pence (1955)^g From Mondo Minerals (2005)

southern Spain and the USA (Arkansas, California and Texas) (Piniakiewicz *et al.*, 1994; Harben & Kuzvart, 1996). These deposits may contain trace amounts of nickel, cobalt and chromium that are derived from their ultramafic protolith. One major talc deposit in eastern USA contains substantial amounts of nickel (up to 0.2%; Rohl *et al.*, 1976). Nickel-substituted talc is also associated with serpentine bodies, at up to 0.5% by weight (Pooley & Rowlands, 1975); pentlandite has been reported in talc from Finland from which it is recovered by flotation (Harben & Kuzvart, 1996). Quartz is uncommon in talc that has mafic or ultramafic protoliths and the fluorine content is generally low (Ross *et al.*, 1968). Chlorite and amphiboles are usually associated with this type of talc deposit although they are commonly separated in space from the talc ore (Vermont). The amphiboles may or may not be asbestiform, depending on the local geological history. A small amount of amphibole asbestos is associated with this type of talc deposit at Soapstone Ridge, GA (USA) and anthophyllite asbestos is abundant in the vicinity of the talc at Dadeville, AL (USA) (Van Gosen *et al.*, 2004). In a few deposits, the parent was mafic rock (Virginia (Schuyler), Georgia and Egypt) (Harben & Kuzvart, 1996).

Table 1.3. Mineral composition (wt%) of talc from various locations

Mineral	Montana	Vermont	North Carolina	New York ^a	California	France
Talc	90–95	80–92	80–92	35–60	85–90	70–90
Tremolite	–	–	–	30–55	0–12	–
Anthophyllite	–	–	0–5	3–10	–	–
Serpentine	–	–	–	2–5	–	–
Quartz	<1	<1	1–3	1–3	<1	<1
Chlorite	2–4	2–4	5–7	–	–	10–30
Dolomite	1–3	1–3	2–4	0–2	0–3	–
Calcite	–	–	–	1–2	–	–
Magnesite	0–5	0–5	–	1–3	–	–

From Harben & Kuzvart (1996)

^a Gouverneur District

(b) Talc derived from magnesium carbonates

Talc deposits formed from the alteration of carbonate and sandy carbonate such as dolomite and limestone are the most important in terms of world production. Two types are recognized: (i) those derived from hydrothermal alteration of unmetamorphosed or minimally metamorphosed dolomite (Australia (Mount Seabrook and Three Springs), China, India, Republic of Korea, the Russian Federation (Onot), northern Spain (Respina) and the USA (Alabama (Winterboro), California (Talc City), Montana (Yellowstone), Washington (Metaline Falls) and West Texas); and (ii) those derived from hydrothermal alteration (including retrograde metamorphism) of regionally metamorphosed siliceous dolomites and other magnesium-rich rocks (Austria (Leogen), Brazil (Brumado), Canada

(Madoc), France (Trimouns), Germany (Wunsiedel), Italy (Chisone Valley), the Russian Federation (Krasnoyarsk), Slovakia (Gemerska Poloma), Spain and the USA (Chatsworth, GA, Death Valley–Kingston Range, CA, Murphy Marble belt, NC, and New York). In a few of these deposits, including the large deposit at Trimouns, France, the talc may be classified as being derived from alumino-silicate rocks (Harben & Kuzvart, 1996; Luzenac, 2004).

Talc derived from magnesium carbonate may contain quartz. Van Gosen *et al.* (2004) suggested that, among the first group, only those that are formed by hydrothermal alteration of dolomites that are in direct contact with igneous bodies are probably accompanied by amphiboles (e.g. Death Valley, CA, USA) and that hydrothermal deposits in carbonates that are formed by relatively low-temperature fluids derived from distant igneous bodies contain no or only very minor amounts of amphibole (Talc City, CA, Southwestern Montana and Allamoore, TX, USA). In some deposits in the second group, amphiboles may be very abundant, especially those formed during high-temperature regional metamorphism of impure dolomites. In the Gouverneur District New York State, for example, non-asbestiform tremolite comprises between 30 and 70% of the talc product (Harben & Kuzvart, 1996).

Gouverneur District New York State talc that is currently marketed under the trade name Nyal is a unique industrial mineral product that can readily be distinguished from all other commercially available industrial talcs based on its mineral content. Nyal 100, for example, contains 30–50% tremolite, 20–40% talc, 20–30% serpentine, 2–10% anthophyllite and 0.14% quartz (R.T. Vanderbilt Company, 2000). The tremolite, anthophyllite and serpentine occur as mineral fragments and not as asbestiform fibres. Tremolite from this deposit has been characterized in detail (Campbell *et al.*, 1980). Nyal also contains asbestiform fibres of talc and talc intergrown on a nanoscale with amphibole (Wylie *et al.*, 1997). Wylie *et al.* (1997) estimated that the abundance of particles that are longer than 5 µm and have an aspect ratio of 3:1 or greater in sample FD14 (identified as a commercial talc product from New York State) is $0.8 \times 10^3/\mu\text{g}$; 62% of these particles were identified as talc, 24% as fragments of tremolite plus a small amount of anthophyllite and 14% as talc intergrown with anthophyllite. Products from other mines in this district before 1964 contained different proportions of anthophyllite and tremolite, which may be asbestiform (Chidester *et al.*, 1964).

(c) *Minerals associated with talc*

Because talc deposits are formed from different protoliths under many different geological conditions, each talc deposit has a combination of mineralogy and mineral habit that is distinctive and, in many cases, unique. The most common minerals found in talc products include chlorite, magnesite, dolomite, tremolite, anthophyllite, serpentine and quartz. However, many other minerals have been reported; these are given in Table 1.4 (Pooley & Rowlands, 1975; Piniakiewicz *et al.*, 1994; Harben & Kuzvart, 1996). Some of these minerals are beneficial to certain applications such as tremolite in ceramics.

Table 1.4. Minerals commonly associated with talc

Mineral group	Name	Ideal formula
Carbonate	Dolomite	$(\text{Ca},\text{Mg})\text{CO}_3$
	Magnesite	MgCO_3
	Breunnerite	$(\text{Mg},\text{Fe})\text{CO}_3$
	Calcite	CaCO_3
	Siderite	FeCO_3
	Ankerite	$\text{Ca}(\text{Fe},\text{Mg},\text{Mn})(\text{CO}_3)_2$
Phyllosilicates	Chlorite	$(\text{Mg},\text{Al},\text{Fe})_{12}(\text{Si},\text{Al})_8\text{O}_{20}(\text{OH})_{16}$
	Serpentine (lizardite and antigorite)	$\text{Mg}_3\text{Si}_2\text{O}_5(\text{OH})_4$
	Phlogopite (mica)	$\text{K}_2(\text{Mg},\text{Fe})_6\text{Si}_6\text{Al}_2\text{O}_{20}(\text{OH})_4$
	Sepiolite	$\text{Mg}_8\text{Si}_{12}\text{O}_{30}(\text{OH})_4(\text{H}_2\text{O})_4$
Amphibole ^a	Tremolite	$\text{Ca}_2\text{Mg}_5\text{Si}_8\text{O}_{22}(\text{OH})_2$
	Anthophyllite	$(\text{Mg},\text{Fe})_7\text{Si}_8\text{O}_{22}(\text{OH})_2$
	Actinolite	$\text{Ca}_2(\text{Mg},\text{Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$
Tectosilicates	Quartz	SiO_2
	Feldspar	$(\text{K},\text{Na})\text{AlSi}_3\text{O}_8$
Oxides	Magnetite	Fe_3O_4
	Ilmenite	FeTiO_3
	Manganese oxide	MnO_2
	Rutile	TiO_2
Sulfides	Pyrite	FeS_2
	Pyrrhotite	FeS
	Pentlandite	$(\text{Fe},\text{Ni})_9\text{S}_8$
Other minerals	Tourmaline ^b	$\text{NaFe}_3\text{Al}_6(\text{BO}_3)_3\text{Si}_6\text{O}_{18}(\text{OH})_3(\text{OH})$
	Graphite	C

Compiled by the Working Group from Pooley & Rowlands (1975); Piniakiewicz *et al.* (1994); Harben & Kuzvart (1996)

^a See Leake *et al.* (1997) for precise nomenclature and chemical composition of the amphibole group.

^b This is the formula for one member of the tourmaline group; chemistry is highly variable.

(d) Chemical composition of talc ore

The variability in the chemical composition of talc ore, talc mineral products and talc rock primarily reflects their mineral composition (see Table 1.2).

1.1.5 *Processing of talc ores and composition of talc products*

Talc ores may be processed by a variety of techniques that include selective mining, hand sorting and milling by roller mills, hammer mills, ball mills, fluid energy mills and jet mills and are classified and separated from other minerals by froth flotation or magnetic separation. Some may be treated with acid and calcined. The particle sizes of talc and the abundance of the associated minerals are determined by characteristics of the ore, methods of processing, and the duration of grinding. Grinding breaks the talc platelets along (001) and disaggregates the particles; prolonged grinding may destroy the crystallinity (Sanchez-Soto *et al.*, 1997; Zbik & Smart, 2005). Roller mills tend to preserve the platy structure and different types of milling affect properties such as flatness, surface roughness, roundness, width and elongation (Yekeler *et al.*, 2004). Talc particles are platy, and sizes reflect the dimension parallel to the plate; data are not available on the thinness of the plates.

Talc products also vary in particle size; median sizes range from ~1 to >20 µm and top sizes range from <10 to >100 µm. The most common designations for fineness are based on US Sieve Series and Tyler equivalence and include 200 mesh (95–98% <74 µm), 325 mesh (95–99% <44 µm) and 400 mesh (95–99% <37 µm) (Zazenski *et al.*, 1995).

Talc products that contain >95% mineral talc are used in cosmetics, baby powder, pharmaceuticals, steatite ceramics, pitch control in the paper industry and as a filler in rubber. Today, the talc in baby powders is >99% 200 mesh (Zazenski *et al.*, 1995). Talc products that contain between 75 and 95% mineral talc are used in paper fillers, reinforced plastics, paint, ceramics and dusting compounds for rubber. Lower-purity talc is used in roofing material, patching compounds, flooring and fertilizers (Piniaskiewicz *et al.*, 1994). Particle sizes, colour and nature of associated minerals also vary among these applications.

1.1.6 *Analysis*

(a) *Analysis of bulk samples*

Talc can be identified from its optical properties by polarized light microscopy and oil immersion, from its X-ray or electron diffraction pattern, from its chemical composition and from differential thermal analysis/thermal gravimetric analysis. Chlorite has similar optical properties. Talc platelets on end and talc intergrown with amphibole in fibrous talc have complex electron diffraction patterns that may resemble other silicates, including amphiboles (Stemple & Brindley, 1960) and sepiolite (Germine, 1987), unless carefully indexed. Anthophyllite and sepiolite have chemical compositions that are very similar to talc and require quantitative chemical analysis to differentiate them, including the use of well characterized standards in the case of dispersive X-ray analysis used in conjunction with electron microscopy. Identification of mixed mineral assemblages by X-ray

diffraction may be difficult because of pattern overlap (Krause, 1977) and X-ray diffraction cannot distinguish asbestiform minerals from other habits.

Particle size distributions that are determined by settling underestimate the abundance of larger particles and overestimate the number of smaller particles because the platy structure results in longer settling times for talc compared with spherically shaped particles of equivalent size. Computer-controlled scanning electron microscopy has been used to provide a more accurate size distribution. Determination of the respirable fraction of bulk materials by these two methods differs significantly (Zazenski *et al.*, 1995).

(b) *Analysis of exposure*

The standard methods for the analysis of airborne exposures in an occupational setting where asbestos is known to be present include those of the Health and Safety Executive (1995) and the Occupational Safety and Health Administration (2005). These methods were designed to provide an index of exposure since they count only particles longer than 5 µm with a length-to-width ratio of 3:1 or more that are visible by phase-contrast microscopy. They do not determine the mineral identity of the particles counted. In a mining environment where many minerals form elongated fragments, the results of fibre counts can be difficult to interpret. In bulk samples of talcum products, for example, Cralley *et al.* (1968) reported that particles longer than 5 µm with a 3:1 aspect ratio in 22 talcum products represented 19% of the particles, which were predominantly talc.

Conversion of fibre counts to gravimetrically based exposure metrics is complicated as this will depend on the particle size. Oestenstad *et al.* (2002) adjusted million particles per cubic foot (mppcf) to milligrams per cubic metre (mg/m³) using the following regression equation:

$$\ln(\text{mg/m}^3) = \ln(\text{mppcf}) \times 0.62 - 1.20$$

All gravimetric measurements to monitor exposure to talc in occupational settings are taken from samples of respirable dust particles. The reader is referred to the Glossary and the monograph on carbon black for further details.

1.2 **Production and use**

1.2.1 *Production*

Talc deposits result from the transformation of existing rocks under hydrothermal activity and are classified according to the parent rock from which they derive. There are three broad types of talc deposit of commercial significance (Luzenac, 2004; EUROTALC, 2005; Industrial Minerals Association-Europe, 2005): (i) talc derived from mafic and ultramafic rocks, which provides about 40% of talc supplies; the crude ore is usually grey and, to be commercially viable, may be upgraded to improve the mineralogy and whiteness (generally by flotation); (ii) talc derived from magnesium carbonates, which provides >50% of world production; and (iii) talc derived from aluminosilicate

rocks, from which about 10% of world production is mined, and which is sometimes found in combination with deposits of magnesium carbonate; the crude ore is generally grey due to the presence of chlorite, but no upgrading is necessary as chlorite performs adequately in the applications of interest.

This wide diversity of origins and types of deposit naturally gives rise to a wide variety of ores and product grades that differ according to their mineralogical composition, colour and crystalline structure (microcrystalline or lamellar) (Luzenac, 2004; EUROTALC, 2005; Industrial Minerals Association-Europe, 2005).

World production of talc and pyrophyllite in both 2003 and 2004 was estimated to be 8.3 million tonnes. Of the total production, approximately 2.15 million tonnes were confirmed to be used for talc production in both 2003 and 2004. China was the leading producer of talc in the world, followed by the USA, India, Brazil (crude) and France (crude). The Republic of Korea was the leading producer of pyrophyllite, followed by Japan and Brazil. Brazil, China, France, India, Japan, the Republic of Korea and the USA produced 84% of talc and pyrophyllite in the world (Table 1.5) (Virta, 2004).

Table 1.5. World production of talc (in tonnes unless otherwise specified)^{a,b}

Country	2000	2001	2002	2003	2004
Argentina	6730	1665	1643	1759	1800
Australia ^c	178 545	173 446	173 741	174 000	173 000
Austria (crude+so) ^d	130 000 ^e	140 000	135 000	135 000	135 000
Bhutan ^d	3700	3800	3900	3900	3900
Brazil (crude)	300 000	397 000	348 000	365 000	370 000
Brazil (marketable product) ^f	7049	6300	5617	5593	5600
Canada (t+p+so)	86 000	90 000	90 000	90 000	90 000
Chile	2421	4177	3537	4374	4400
China (unspecified) ^d	3 500 000	3 500 000	2 500 000	3 000 000	3 000 000
Colombia (t+p+so) ^d	15 000	15 000	15 000	15 000	15 000
Egypt (t+p+so+st) ^d	40 000	40 000	40 000	40 000	40 000
France (crude) ^d	350 000	350 000	350 000	350 000	350 000
Germany (marketable+st+t) ^d	8000	10 000	10 000	10 000	10 000
Hungary ^d	500	500	500	500	500
India (st)	545 000	546 000	550 000	552 000	550 000
Iran ^{d,g}	25 000	25 000	25 000	25 000	30 000
Italy (t+st) ^d	140 000	140 000	140 000	140 000	140 000
Japan	50 000	45 000	40 000	40 000	35 000
Macedonia	562	557	550	550	600
Mexico	20 569	77 650	111 621	114 870	115 000
Morocco	12 522	27 246	39 612	1959	2000
Nepal ^h	5852	3923	2621	2500	2400
Norway (t+so+st) ^d	27 000	27 000	28 000	28 000	28 000
North Korea (unspecified) ^d	120 000	120 000	110 000	110 000	110 000
Paraguay (t+p+so) ^d	200	200	200	200	200
Peru	9668	11 165	10 685	10 791	10 000
Portugal ^d	8200	8200	8200	8200	8000
Republic of Korea	11 344	47 712	37 863	47 911	48 000
Romania	7850	7270	7292	10 082	10 000
Russia ^d	100 000	100 000	100 000	100 000	100 000

Table 1.5 (contd)

Country	2000	2001	2002	2003	2004
Slovakia	1800	2600	2290	1000	1500
South Africa	5600	3218	2511	4472	12 065 ^c
Spain (t+st) ^d	100 000	100 000	100 000	100 000	100 000
Sweden (t+so)	20 000	15 000	15 000	15 000	14 000
Taiwan	—	130	27	466	411 ^c
Thailand	7390	6838	1702	8501	8500
United Kingdom (t+p+so) ^d	5000	5000	5000	5000	5000
USA	851 000	863 000	828 000	840 000	857 000 ^c
Uruguay (t+p+so)	2903	1694	1700	1700	1700
Zimbabwe	989	1273	911	196	— ^e

From Virta (2004)

p, pyrophyllite; so, soapstone; st, steatite; t, talc

^a World totals; data from the USA and estimated data are rounded to no more than three significant digits; may not add to totals shown.

^b Table includes data available through to April 19 2005.

^c Data based on Australian fiscal year ending 30 June of the year stated.

^d estimated

^e Reported figure

^f Direct sales and/or beneficiated (marketable product)

^g Data based on Iranian fiscal year beginning 21 March of the year stated

^h Data based on Nepalese fiscal year beginning mid-July of the year stated

1.2.2 Use

The properties of mineral talc (platyness, softness, hydrophobicity, organophilicity and inertness) and the mineralogical composition of talc products govern their specific applications in many industries and processes including paint, polymers, paper, ceramics, animal feed, rubber, roofing, fertilizers, cosmetics and pharmaceuticals. The principal technical applications of talc in commercial products are as an anti-sticking and anti-caking agent, lubricant, carrier, thickener, strengthening and smoothing filler and absorbent (Industrial Minerals Association-Europe, 2005).

(a) End-use categories

(i) Agriculture and food

Talc is used as an anti-caking agent, dispersing agent and die lubricant in animal feed and fertilizers. In premixes and agricultural chemicals, it is used as an inert carrier. Talc is also used as an anti-stick coating agent in several foods and as a processing aid in the production of olive oil. (Luzenac, 2004; Industrial Minerals Association-Europe, 2005).

Agricultural chemicals. Talc is a functional carrier in agricultural products that offers very low moisture equilibrium, relative hydrophobicity and chemical inertness. Costs are reduced by extending expensive chemicals and improving the dispersion and flow of

active ingredients. Talc is appropriate for garden dusts, flea and tick powders, seed treatments and biocides (Luzenac, 2004).

Anti-caking and homogenization. Talc improves the flowability of difficult raw materials, e.g. oilseed meal and finished products, and feeds with high loads of sticky ingredients such as molasses, oil, fatty products, urea, milk powder and sugar. The smooth and flat lamellae of talc cover each particle and help them to flow freely. As they are naturally water-repellent, talc particles form a barrier when they envelop other particles and reduce the evaporation and uptake of water within the product mass. Talc platelets help different constituents to blend more easily and facilitate the dispersion of sticky ingredients (Luzenac, 2004).

Die lubricant. Talc is a cost-effective die lubricant especially for high-fibre, high-sugar and high-mineral formulations and pelleted feeds (Luzenac, 2004).

Fertilizers. Talc is used as an anti-caking agent in both prilled (pelleted or granulated) ammonium nitrate and granular fertilizers. Talc particles reduce the absorption of moisture and prevent the formation of hydrate bridges, which enables longer storage periods. In Europe, amine-coated talcs are marketed with enhanced adhesion properties that enable the amine contents to be reduced and result in lower dust levels and less environmental impact (Luzenac, 2004).

Foods. Talc is an effective anti-stick coating agent that is used in several foods, such as chewing gum, candies and cured meats (Luzenac, 2004).

Processing of olive oil. In the production of olive oil, talc acts as a natural processing aid that improves extraction and increases the yield of virgin olive oil (Luzenac, 2004).

Premixes. Talc is used as an inert carrier for active premix ingredients. Certain talc grades have been specifically designed for dust-free, high-specification requirements (Luzenac, 2004).

(ii) *Ceramics*

Talc imparts a wide range of properties to floor and wall tiles and sanitary ware, tableware, refractory goods and technical ceramic products. In traditional building ceramics (tiles and sanitary ware), it is used essentially as a flux to enable firing temperatures and cycles to be reduced. In refractory applications, talcs that are rich in chlorite are used to improve thermal shock resistance. Talcs with a microcrystalline form are the most appropriate for steatite ceramics. During firing, the talc is transformed into enstatite, which possesses electro-insulating properties. Talcs with a very low iron content are particularly suitable for use in frit, engobe [underglaze] and glaze compositions (Luzenac, 2004; Industrial Minerals Association-Europe, 2005).

(iii) *Coatings*

Talcs confer several properties on coatings. In interior and exterior decorative paints, they act as extenders to improve hiding power and the efficiency of titanium dioxide. The lamellar platelets of talc make paint easier to apply and improve cracking resistance and sagging, and also enhance matting. In anti-corrosion primers, talcs are used to improve

resistance to corrosion and adhesion of the paint. They are also used in inks, jointing compounds, putties and adhesives (Luzenac, 2004; Industrial Minerals Association-Europe, 2005).

(iv) *Paper*

Talcs are used in both uncoated and coated rotogravure papers in which they improve printability, reduce surface friction and enhance handling characteristics. They also improve mattness and reduce ink scuff on offset papers. When used as pitch-control agents, talcs 'clean' the papermaking process by adsorbing any sticky resinous particles in the pulp onto their platy surfaces, and thereby prevent the agglomeration and deposition of these on the felts and calenders. In contrast to chemical pitch-control products that pollute the process water, talc is removed with the pulp, which enables the papermaker to operate more easily in a closed circuit. In specialty papers such as coloured papers or labels, talcs help to improve quality and productivity (Luzenac, 2004; Industrial Minerals Association-Europe, 2005).

(v) *Personal care*

As it is soft to the touch and inert, talc has been valued for centuries as a body powder. Today, it also plays an important role in many cosmetic products, including products for feminine hygiene and baby powders, and provides the silkiness in blushes, powder compacts and eye shadows, the transparency of foundations and the sheen of beauty creams. In pharmaceutical products, talc is an important excipient that is used as a glidant, lubricant and diluent. Soap manufacturers also use talc to enhance the performance of skin care products (Luzenac, 2004; Industrial Minerals Association-Europe, 2005). Table 1.6 presents information on levels of talc in cosmetic products in the USA and Table 1.7 gives the composition of some examples of products that are used for body care.

(vi) *Plastics*

Talcs impart a variety of properties to polypropylene, such as greater stiffness and improved dimensional stability in automotive parts, household appliances and white goods. Advanced milling technology is required to obtain the finest talcs without diminishing the reinforcing power of their lamellar structure. Talcs are also used for the anti-blocking of linear low-density polyethylene and as a nucleating agent in semicrystalline polymers. In polypropylene that is used in food packaging applications, talc is a highly effective reinforcing filler. The grades of talc used for this purpose include calcined, surface-treated, ultrafine grind and high aspect ratio (Luzenac, 2004; Industrial Minerals Association-Europe, 2005).

(vii) *Roofing*

Talc is a high-performance product that is used to back surfacing asphalt shingles. The use of talc is even more important in the growing market for laminated shingles in

which handling is more complex, wear and tear on machinery is greater, cutting is doubled and adhesion of the interlayer is critical (Luzenac, 2004).

Table 1.6. The number of cosmetic products in the Cosmetics and Toiletries Formulations Database in the USA that contain talc or talcum

Product categories	No. of products
Antiperspirants and deodorants	22
Baby products	6
Bath and shower products	2
Beauty aids ^a	184
Creams	14
Hair care products	1
Lipsticks	5
Lotions	1
Shampoos	1
Shaving products	2
Sun care products	3
Miscellaneous ^b	8

Compiled by the Working Group from Flick (2005)

^a Beauty aids includes aerosol talc products, face masks, foundations, body oils, make-up bases, concealers, blushes, body powders, rouge, make-up, compact powders, eye shadows, dusting powders, eyebrow pencils, pressed powder products, face powders, mascaras, liquid talc products and powder cleansers

^b Miscellaneous includes aerosol talc foams, wound ointments, foundations with extracts, foot powders, liquid foundations and sport tints

(viii) Rubber

Talcs reduce the viscosity of rubber compounds and thereby facilitate the processing of moulded parts. They also improve the quality of extrudates, which increases production rates and enhances the resistance to ultraviolet (UV) radiation of exterior parts such as automotive profiles. In sealants and gaskets, they provide compression resistance, while in pharmaceutical stoppers, they create a barrier against liquids. Talcs are used as insulators in cables and as processing aids in tyre manufacture (Luzenac, 2004; Industrial Minerals Association-Europe, 2005).

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Table 1.7. Composition of some products used for body care

Product	Wt% talc	Other components	Wt% other components
Dusting powder	97.7	Perfume oil	0.8
		GLUCAM P-20	1.5
		Preservative	q.s.
Dusting powder	91.6	Magnesium carbonate	3.0
		Zinc stearate	3.0
		Triclosan	0.2
		Perfume oil	0.7
		GLUCAM P-20	1.5
		Preservative	q.s.
Velvety dusting powder	77.4	Aluminum starch, Octenyl succinate	20.0
		Zinc stearate	2.0
		Methylparaben	0.10
		Propylparaben	0.10
		Germall II	0.20
		Fragrance	0.20
Face and body powder	89.30	Boron nitride	10.00
		Methylparaben	0.15
		Propylparaben	0.20
		Imidazolidinyl urea	0.05
		Iron oxide (yellow)	0.20
		Iron oxide (red)	0.10
Baby powder	72	DYNASAN 114	2.0
		Magnesium stearate	8.0
		Kaolin	18.0
After-bath talc	92.5	Perfume oil	5.0
		PPG-20 methyl glucose ether	1.50
		Macadamia nut oil	1.00
Body powder	4.0	Boron nitride	5.0
		Silica	2.5
		Starch	30.2
		Kaolin	10.0
		Magnesium stearate	1.00
		Bentone 38/Quaternium18,	1.0
		Hectorite	
		Isopropyl myristate	6.0
		Perfume	1.8
		Pigments	q.s

Table 1.7 (contd)

Product	Wt% talc	Other components	Wt% other components
Powder for babies and children	20.0	Kaolin	20.0
		Rice starch	51.0
		Zinc stearate	5.0
		Eutanol G	2.0
		Lanette O	2.0
Dispersing bath powder	0	Kukui nut oil	1.0
		Phenyl trimethicone	1.0
		Cyclomethicone	2.0
		Fragrance	1.5
		Ethoxydiglycol	2.0
		Oleth-2	2.50
		Oleamidopropyl PG, dimonium chlorite	2.0
		Topopheryl acetate (Vitamin E)	0.50
		Cornstarch	86.00
		Silica	1.50
Body powder	0	Zinc stearate	5.0
		Zinc oxide	5.0
		Magnesium carbonate	15.0
		Kaopolite TLC	75.0
Talc-free body powder	0	Cornstarch	88.45
		Kaolin	5.0
		Mica	2.0
		Titanium dioxide	2.0
		Red mica and titanium dioxide	0.25
		Tapioca starch	2.0
		Methylparaben	0.10
		Propylparaben	0.05
		Imidazolinidyl urea	0.15

From Flick (2005)

The Working Group was aware that these data are not representative of all products

q.s., quantum satis (sufficient quantity)

(ix) *Wastewater treatment*

Specialty talc can improve the performance of biological wastewater treatment plants. The talc particles ballast the flocs of bacteria and accelerate their sedimentation (Industrial Minerals Association-Europe, 2005).

(x) *Other*

Talc is used as an anti-sticking agent to powder moulds in foundries and in the manufacture of pharmaceuticals and rubber or on conveyor belts that carry foodstuffs. It is also used in other products, such as condoms and surgery gloves. Particle-wood boards (chip boards) are powdered with talc to avoid sticking when stockpiled. Talcs are also used as smooth fillers, for example in the 'lead' of colouring pencils and in putties (where it can be the major component) (Industrial Minerals Association-Europe, 2005).

Talc had been used as a sclerosing agent in the pleural space for the treatment of spontaneous pneumothoraces. Talc is also used for pleurodesis in the treatment of malignant pleural effusions (Dresler *et al.*, 2005). The products used for these purposes contain 95% talc and 5% chlorite and dolomite.

(b) *Use patterns*

The worldwide use pattern for talc in 2000 was: paper, 30%; ceramics, 28%; refractories, 11%; plastics, 6%; a filler or pigment in paints, 5%; roofing, 5%; cement, 3%; cosmetics, 2%; and other miscellaneous uses, 10% (art sculpture, asphalt filler, autobody filler, construction caulks, agriculture and food, flooring and joint compounds) (Roskill Information Services Ltd, 2003). The use pattern for talc in the USA in 2004 was: ceramics, 32%; paints, 19%; paper, 16%; roofing, 6%; plastics, 4%; rubber, 3%; cosmetics, 1%; and other, 19% (Virta, 2004). The use of talc in cosmetics in the USA decreased from 34 000 tonnes in 1993 to 5000 tonnes in 2004 (Virta, 2004).

The estimated world consumption of talc by geographical region in 2000 was: Asia, 43%; western Europe, 19%; North and central America, 17%; South America, 8%; Indian subcontinent and Middle East, 8%; Africa, 2%; eastern Europe and Commonwealth of Independent States countries, 2%; and Australia and New Zealand, 1% (Roskill Information Services Ltd, 2003).

1.3 Occurrence and exposure1.3.1 *Natural occurrence*

Talc is found in small amounts in metamorphic mafic and ultramafic rocks and in carbonates. These metamorphic rocks crop out in mountain belts such as the Alps, the Appalachians and the Himalayas and in ancient continental shields such as the Canadian shield in New York and Canada.

The occurrence of talc deposits of commercial importance is described extensively in Section 1.1.4.

1.3.2 *Occupational exposure*

Exposure to talc dust occurs during its mining, crushing, separating, bagging and loading and in various industries that use talc (see Section 1.2.2). This section reviews

exposure to talc during its mining and milling, other than that from the Gouverneur District New York State mines, and in user industries, whenever this information is available. Exposure to talc is also described, where possible, for those industries in which epidemiological studies have been carried out in relation to the occurrence of cancer.

(a) *Mining and milling*

Before the 1970s, exposure measurements were made by collecting particles in an impinger and counting them by optical microscopy. Concentrations were thus expressed as million particles per cubic foot of air (mppcf). More recent studies have described levels of exposure to dust that were assessed using gravimetric measurement techniques.

Table 1.8 describes studies of exposure to talc in mines and mills. In Georgia, USA, average exposures to dust were 1440 mppcf ($\sim 50\,854$ particles/cm³) for miners who used jackhammer drills and 52 mppcf (~ 1836 particles/cm³) for millers. The talc was reported to contain 45% tremolite and 45% talc, with little or no quartz (Dreessen, 1933). Average dust concentrations in a talc mine were reported to range from 32 to 855 mppcf (~ 1130 to $30\,195$ particles/cm³; six samples), whereas those in mills ranged from 17 to 1672 mppcf (~ 600 to $59\,000$ particles/cm³; 14 samples). The dust was reported to contain 70% talc, 20–30% dolomite and 10% tremolite, and no quartz except for occasional fragments; its morphology was described as ‘bladed crystals’. Highest exposures to dust occurred during bagging operations (Dreessen & DallaValle, 1935).

Concentrations of respirable dust in mass samples from three Vermont talc mines and mills surveyed in 1975–76 are given in Table 1.9. Geometric mean exposures to respirable dust ranged from 0.5 to 5.1 mg/m³ in the mines and from 0.5 to 2.9 mg/m³ in the mills; however, exposures in the mills were generally higher than those in the mines. Optical fibre counts as high as 60 fibres/cm³ were reported. Subsequent analyses of these samples by scanning electron microscopy showed that they consisted of rolled talc and elongated talc particles. X-Ray diffraction analyses of bulk samples from these mines and mills showed that talc and magnesite were the major (20–100%) mineral components, chlorite and dolomite were minor (5–20%) components and calcite, quartz, biotite, ankerite, chromite, phlogopite and oligoclase were present in small amounts (<5%). Trace amounts of quartz were found in 15% of the samples (Boundy *et al.*, 1979). Dust from one closed mine was reported to contain tremolite microinclusions, but its fibrosity was not documented (Selevan *et al.*, 1979).

A cross-sectional study of occupational exposures in talc mines and mills in the USA was conducted by the National Institute for Occupational Safety and Health; the results are summarized in Table 1.10. Bulk samples from each region were analysed by transmission electron microscopy: no fibre was found in any sample of Montana talc; fibrous tremolite and antigorite were reported in Texan talcs (0.5–3.0 μm in diameter, 4–30 μm in length); and talcs from North Carolina contained particles with length:diameter ratios as high as 100:1, with some <0.1 μm in diameter (Greife, 1980; Gamble *et al.*, 1982). Van Gosen *et al.* (2004) recently reported that the Texan talc contained little or no amphibole.

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Table 1.8. Studies of occupational exposures in talc mines and mills

Reference	Location of talc deposit	Date of exposure measurements	Method of measurement	Other minerals present
Dreessen (1933)	Georgia, USA	Pre-1933	Impinger	Tremolite
Dreessen & DallaValle (1935)	Georgia, USA	Pre-1935	Impinger	Tremolite, dolomite
Rubino <i>et al.</i> (1976); Coggiola <i>et al.</i> (2003)	Piedmont, Italy	1946–95	–	Quartz (radon, diesel exhaust)
Rubino <i>et al.</i> (1976)	Piedmont, Italy	1920–75	Impinger	Small amounts of tremolite
Boundy <i>et al.</i> (1979)	Vermont, USA	1975–76	Optical and electron microscopy fibre counts	Dolomite, calcite, magnesite, chlorite, traces of other minerals
Greife (1980); Gamble <i>et al.</i> (1982)	Montana, Texas and North Carolina, USA	1977–80	Gravimetric	Varied by location studied
Wild <i>et al.</i> (1995, 2002)	France, Austria	1986–92	Gravimetric (CIP personal sampler)	Quartz: France, <3%; Austria, <4%

CIP, capteur individuel de poussière [personal dust sampler]

Table 1.9. Concentrations (mg/m³) of respirable dust in Vermont talc mines and mills

Company	Area	Summer 1975		Winter 1976	
		No. of samples	Geometric mean (mg/m ³)	No. of samples	Geometric mean (mg/m ³)
A	Underground mine	18	0.6	16	0.5
	Mill (1st shift)	4	1.7	13	1.7
	Mill (2nd shift)	6	0.5	3	1.5
B	Underground mine	15	1.5	23	0.9
	Mill (1st shift)	22	1.8	42	1.8
	Mill (2nd shift)	12	2.9	16	1.9
C	Underground mine	12	0.5	19	0.7
	Walk-in mine	7	1.2		
	Walk-in mine			6	1.7
	Open-pit mine	2	5.1	—	—
	Mill No. 1 (1st shift)	12	0.9	20	1.1
	Mill No. 1 (3rd shift)	3	0.8	4	1.4
	Mill No. 2 (1st shift)	11	1.0	8	0.5
	Mill No. 2 (2nd shift)	13	0.8	3	1.1

From Boundy *et al.* (1979)**Table 1.10. Concentrations of respirable dust in 275 samples from talc mines and mills located in Montana, Texas and North Carolina, USA**

Samples	Geometric mean (mg/m ³)		
	Montana	Texas	North Carolina
From mines	0.66 (0.47–0.92) ^a	0.45 (0.18–0.71)	0.14 (0.07–0.31)
From mills	1.1 (0.85–1.41)	1.56 (0.96–2.54)	0.26 (1.13–0.51)
Bulk talc samples (% free silica)	<0.8	2.23	1.45

Adapted from Greife (1980); Gamble *et al.* (1982)^a In parentheses, 95% frequency interval

Analysis of 362 personal samples of respirable dust collected over a full shift from talc mines and mills by the Mine Safety and Health Administration in the USA showed the median dust exposure to be 1.20 mg/m³; 90% of all exposures were <2.78 mg/m³ (National Institute for Occupational Safety and Health, 1979).

Before the adoption of technical preventive measures in 1950, exposures in the talc operation in the Germanasca and Chisone Valley (Piedmont), Italy, were reported to be approximately 800 mppcf [$\sim 28\,250$ particles/cm³] in the mines and 25 mppcf [~ 883 particles/cm³] in the mills. Exposures in both areas were reduced to less than 10 mppcf [~ 353 particles/cm³] after 1965 when improved ventilation techniques and wet drilling procedures were introduced. Mineralogical analyses of the footwall rocks demonstrated that they contained quartz, muscovite, chlorite, garnet, calcite, magnesite and small quantities of other minerals. In a few specimens of footwall rocks, a small amount of tremolite was detected, but no other type of amphibole or chrysotile. Talc specimens from these mines were found very commonly to contain chlorite, but no amphibole or chrysotile minerals. The quartz content of powdered talc specimens was generally below the detection limits of X-ray diffraction (Rubino *et al.*, 1976). In recent years, the mean exposure to respirable dust was 1.1 mg/m³ (range, 0.5–2.5 mg/m³), while the mean exposure to talc alone was 1.0 mg/m³ (range, 0.3–2.0 mg/m³). The authors stated that there was a remarkable difference in the amount of quartz in air dust in mines and mills and within jobs in the mine between drilling and other occupations. This was mainly due to the high content of quartz in footwall rocks, rather than to the absence of quartz particles in talc minerals (Coggiola *et al.*, 2003). [The Working Group noted that the analytical methods were not described in detail and the mineral habit of the tremolite was not documented.]

Wild *et al.* (1995) reported on a survey of the respiratory health of workers in a French talc producing factory. At this quarry, crude talc was extracted and transported directly to the mill using an overhead cable. The extracted ore consisted of a mixture of talc, chlorite, some dolomite (<3%), occasionally quartz (<3%) and traces of calcite, apatite, pyrite and mica. Amphiboles were not detected. A total of 1440 personal samples were taken between 1986 and 1991. The mean levels of exposure to respirable dust ranged from 0.5 mg/m³ for secretaries, managerial staff and outdoor workers who handled the railway wagons to 15 mg/m³ for site cleaning staff. In 1991, only one exposure group of four maintenance workers was estimated to have a mean exposure in excess of 5 mg/m³. However, the probability of exceeding an exposure level of 5 mg/m³ was more than 10% for most maintenance and some production workers. This was explained by the high variability of exposure among maintenance workers; eight of 10 groups of workers in the maintenance workshop had geometric standard deviations >3. Exposure was found to be more homogeneous among the production workers. The authors claimed that the introduction of centralized aspiration devices and new working procedures had resulted in lower levels of exposure. Mean levels of exposure in the in the past were estimated to have been up to 60 mg/m³, especially for workers storing jute bags of talc in wagons. Before 1985, the highest levels of exposure to dust for site cleaning staff were estimated to be 30 mg/m³; for sacking and drying, exposure levels in the workplace before 1975 were estimated to be 20 mg/m³.

Wild *et al.* (2002) also provided some additional exposure information for three Austrian mines and their respective mills in the Styrian Alps. The ore mined at one site

(site B) consisted of a talc–chlorite mixture with gänge [dead rock] inclusions of about 25% (mainly alumino-silicate rock). The gänge was dumped in the mine so that the milled product was talc–chlorite and contained between 0.5 and 4% quartz. At site C, the material mined was a talc–dolomite aggregation with a medium talc content of 25%. The amount of quartz in the end-product was below 1%. However, materials from certain parts of this mine that were rich in dolomite could have contained 2–3% quartz. At site D, a light greyish quartz–chlorite–mica schist (alumino-silicate rock that consisted of an aggregation of more or less equal proportions of mica, chlorite and quartz) was mined and milled. Analyses of dust from the lungs and lymph nodes of employees in the Austrian talc industry confirmed the presence of quartz and the absence of amphibole and serpentine (Friedrichs, 1987). Table 1.11 summarizes the levels of exposure reported in the French and Austrian talc mines and associated mills.

Table 1.11. Levels (mg/m³) of exposure to respirable dust in one French and two Austrian talc mines and associated mills

Exposure group	Occupation	Mine/mill	No. of samples	Mean	Range	Date
No exposure	Office workers	French talc quarry	168	0.2		1986
Low exposure (<5 mg/m ³)	Maintenance workers, garage mechanics, production workers with dust control/LEV	French talc quarry	100	0.5–2.6	0.11–17	1986
		Austrian mine B	173		0.02–4.61	1988–92
		Austrian mine C	33		0.02–4.1	1991–92
Median exposure (5–30 mg/m ³)	Recent production workers	French mine A	193	3.5–25.6	0.21–134	NR
		Austrian mines B and C	17		6.5–19.6	NR
High exposure (>30 mg/m ³)	Milling, maintenance, cleaning	Austria	3		73–159	End of 1980s

From Wild *et al.* (1995, 2002)

LEV, local exhaust ventilation; NR, not reported

Several samples were collected from a crushing, grinding and talcum powder packing unit at a plant in Pakistan to measure different particle sizes (Jehan, 1984). In total, seven 1-hour samples were collected, one for total suspended particles (concentration, 6.14 mg/m³), one for particulate matter (PM) <10 µm (1.12 mg/m³), one for PM <7 µm (1.93 mg/m³), one for PM <5 µm (0.40 mg/m³), one for PM <3 µm (0.26 mg/m³), one for

PM <2 μm (0.05 mg/m^3) and one for PM >1 μm (1.55 mg/m^3). Further analyses of the samples with PM <10 μm and <2 μm by scanning electron microscopy showed that the fibre concentration was 0.25 fibres/ cm^3 and 0.12 fibres/ cm^3 , respectively. Analyses by polarized light microscopy indicated the presence of asbestiform tremolite, chrysotile and anthophyllite in these samples.

(b) *User industries*

Only limited information is available on exposures in secondary industries in which talc is used or processed further. Results from some surveys are summarized in Table 1.12.

Table 1.12. Mineral composition of talc used for dusting in the rubber industry in the USA

Reference	Location	Date	Mineral composition	Method of analysis
Hogue & Mallette (1949)	Vermont	1943–48	Stated to be ‘pure talc’	Impinger
Dement & Shuler (1972)	Canton, MA	1972	2–3% quartz	Gravimetric, optical fibre counts
Fine <i>et al.</i> (1976)	Vermont	1972–74	Trace of quartz (<1%), <2 fibres/ cm^3	Gravimetric

Personal air samples collected in a rubber band production plant, where housekeeping, ventilation and work practices were poor and talc was used as an anti-sticking agent, had time-weighted average (TWA) concentrations of respirable dust of 2.5–7.8 mg/m^3 (average, 4.8 mg/m^3) for extruders, 5.3 and 6.1 mg/m^3 for vulcanizers and 0.9 and 1.3 mg/m^3 for cutters. Exposures to total dust were found to range from 5.4 to 199 mg/m^3 . The talc was reported to contain 2–3% quartz. Within these exposures, 4.7–19.2 fibres were >5 $\mu\text{m}/\text{cm}^3$ as measured by phase-contrast optical microscopy (Dement & Shuler, 1972). [The Working Group noted that no electron microscopic analysis was conducted to confirm the identity of the fibres; however, most of these were probably not asbestos.]

Concentrations of respirable dust in two rubber manufacturing plants where Vermont talc was used as an anti-sticking agent are shown in Table 1.13. Eighteen of 21 samples analysed for quartz contained less than 1% by weight. In 12 samples analysed for fibres, using phase-contrast microscopic techniques for asbestos, all concentrations were less than 2 fibres/ cm^3 . No electron microscopic fibre analysis was reported (Fine *et al.*, 1976). Hogue and Mallette (1949) found an average dust concentration of 15–50 mppcf [\sim 530–1765 particles/ cm^3] talc in two rubber plants that used Vermont talc. Average exposures were 20 mppcf [\sim 706 particles/ cm^3] for tube machine operators, 35 mppcf

[1236 particles/cm³] for tube ‘bookers’, 15 mppcf [~530 particles/cm³] for tube cure men and 50 mppcf [~1765 particles/cm³] for ‘line rerollers’.

Table 1.13. Concentrations of respirable dust in rubber processing plants that used talc

Location	No. of samples	Average dust concentration (mg/m ³)
<i>Plant A</i>		
Lorry and bus inner tubes (splicer)	7	0.60
Lorry and bus inner tubes (cureman)	6	1.41
‘Tuber operator’	3	0.47
‘Booker’	3	0.74
Farm service inner tubes (splicer)	6	0.82
Farm service inner tubes (cureman)	2	0.91
<i>Plant B</i>		
Rubber band area	6	3.55
Gum engraving room	6	0.64
Hose extruding	4	0.51
Curing heavy duty flaps	3	1.29
‘Dust room’	2	0.59

From Fine *et al.* (1976)

In a mortality study of lung cancer and respiratory disease among pottery workers exposed to silica and talc, Thomas and Stewart (1987) estimated exposure to non-asbestiform talc and tremolitic talc. Exposure to talc occurred almost exclusively in the cast shop. Montana steatite talc that had been used to dust moulds since 1955 appeared to contain no asbestiform talc (Gamble *et al.*, 1982; Grexa & Parmentier, 1979). However, before 1955, flint and ground clay had been used to dust the moulds. Up to 1976, tremolitic talc had been used in some glazes. No measurements of airborne talc or silica were available, and exposure estimates were based on detailed knowledge of industrial processes and job duties. All exposures to talc were associated with high exposure to quartz from the clays. Quartz particles from clay are smaller than approximately 4 µm.

Kauppinen *et al.* (1997) developed an international database of exposure measurements in the pulp, paper and paper product industries. In total, 63 measurements for talc were included in this database—four measurements in the pulp production and 59 in paper or paperboard production and recycling; 6% of the samples exceeded the 8-hour TWA threshold limit value (TLV) for talc of 2 mg/m³ respirable dust (ACGIH® Worldwide, 2005). [No information was provided on the methods of measurement, the time period when these measurements were taken or the actual processes and the materials used during these measurements. As only a limited number of measurements were available, it is improbable that these results are representative of exposure to talc in this industry.]

Kauppinen *et al.* (2002) described the prevalence of exposure to talc among workers in the on-machine coating of paper. In total, 25 departments were assessed: in 60% of the departments, more than 5% of the workers were exposed to talc, with a median prevalence of exposure of 51–90%. The median level of exposure was assessed as medium (0.6–2 mg/m³) by a team of occupational hygienists.

Pooley and Rowlands (1975) examined talc imported into the United Kingdom. These talcs were used in a variety of industries, including cosmetics. Only one of the samples examined contained tremolite (>30%). [The number of samples examined and their use were not given. The electron micrograph of the sample identified as tremolite and the concentration of tremolite are consistent with the Gouverneur District New York State talc, which is unlikely to have been used in cosmetics.] All other elongated particles detected in the samples were identified as laths or rolled sheets of talc, chlorite or sepiolite (several samples).

1.3.3 *Consumer exposure*

(a) *Mineralogical characterization*

Two studies that were conducted between 1968 and 1977 examined the mineralogy of consumer talc in the USA.

Cralley *et al.* (1968) examined 22 cosmetic talc products that were purchased off the shelf for particles >5 µm with a 3:1 or greater aspect ratio (diameter:length) and found that on average 19% of the particles met these dimensional criteria. [No additional information was provided on the source of the talc products, but the Working Group noted that the authors were located in Cincinnati, OH, USA.] The authors concluded that these ‘fibres’ were predominantly talc, but suggested that some may have been anthophyllite, tremolite, pyrophyllite or chrysotile. [The Working Group noted that no data were provided to support this statement. The statement was based only on the fact that these minerals have been reported to occur in some talc deposits.] Using X-ray diffraction, quartz was found at a level of 0.2–53.4% in these samples. No limit of detection was given, but the lowest concentration reported was 0.2 wt%. Analysis for other minerals was not carried out.

Rohl *et al.* (1976) examined 20 body powders, baby powders and facial talcums and one pharmaceutical talc, all of which were purchased at retail stores in New York City between 1971 and 1975. Based on X-ray diffraction, optical microscopy and transmission electron microscopy, the concentration of tremolite, anthophyllite and quartz was estimated and the presence of several other minerals was established (see Tables 1.14 and 1.15). One of the 21 samples was composed entirely of cornstarch and one contained primarily pyrophyllite and only a small amount of talc. Quartz was present in nine of the 21 samples, tremolite was reported in nine, anthophyllite in seven and serpentine in two samples. Chrysotile was confirmed by transmission electron microscopy in these samples, but no estimates of the concentrations were provided. Krause (1977), in a review of this study, pointed out that the overlap of the X-ray diffraction patterns of tremolite and

anthophyllite makes accurate estimation of their concentration by this method impossible. A similar problem was pointed out for estimates of the concentration of quartz because of overlap with several talc peaks. [The Working Group believed that these criticisms were reasonable and that little reliance can be placed on the reported concentration of tremolite or anthophyllite. The Working Group also noted that Rohl *et al.* (1976) stated that their methodology did not distinguish between asbestos and non-asbestiform mineral fragments. In addition, the representativeness of these samples for other countries or for other areas of the USA is unclear.]

Table 1.14. Concentrations of minerals in 20 samples of body powders, baby powders and facial talcums and one sample of pharmaceutical talc

Mineral	No. of samples	Concentration range (wt%)
Quartz	9	1.6–35.1
Tremolite ^a	9	0.1–10.3
Anthophyllite ^a	7	2.1–11.4
Chrysotile	2	<0.5 ^b

From Rohl *et al.* (1976)

^a Six samples contained both minerals, which resulted in uncertainty about the absolute concentrations given for each mineral.

^b Visual estimates by transmission electron microscopy were given as 0.25–0.5%, but no methodology was provided.

Table 1.15. Qualitative measurements of minerals other than anthophyllite, chrysotile, quartz or tremolite in 20 samples of body powders, baby powders and facial talcums and one sample of pharmaceutical talc

Mineral	No. of samples in which the mineral was present
Talc	20 ^a
Chlorite	16 ^b
Calcite	8 ^b
Phlogopite	3 ^b
Pyrophyllite	2 ^b
Dolomite	1 ^b
Kaolin	1 ^b

From Rohl *et al.* (1976)

^a Talc was the major mineral in 19 of the 20 samples.

^b Present in quantities above trace amounts

Paoletti *et al.* (1984) examined talc powders that were used in pharmaceutical and cosmetic preparations. Tremolite was identified in two of six cosmetic talcs on the Italian market. Six of 14 samples provide by the European Pharmacopoeia contained either tremolite, anthophyllite or chrysotile. [No information was provided on the concentration of minerals, including tremolite and quartz, or on the time of purchase.]

Jehan (1984) reported on commercial cosmetic-grade talc (baby and body talcum powder) used in Pakistan between 2000 and 2004. Sixty samples were analysed using atomic absorption techniques, X-ray diffraction, polarized light microscopy and scanning electron microscopy, and the presence of asbestiform chrysotile, both asbestiform and non-asbestiform tremolite and anthophyllite was identified. Asbestiform varieties of tremolite and anthophyllite were uncommon, while chrysotile was common. Respirable quartz was also identified in most (80%) of the samples.

Some products listed by the Cosmetic and Toiletries Formulations Database are shown in Table 1.7. Listing is voluntary and may not be representative of products that are on the market. Tables 1.16 and 1.17 present the average mineral composition of commercial products that were sold under the name of talc in North America and Europe, respectively, in the late 1980s.

(b) *Use of talc for feminine hygiene*

The use of body powder for feminine hygiene can be estimated from the prevalence reported for controls in case-control studies that investigated the association between the use of cosmetic talc for feminine hygiene and the risk for ovarian cancer.

The prevalence of ever use in these studies is summarized in Table 1.18. Higher prevalences were generally reported in studies from Canada, the United Kingdom and the USA (up to 59%), whereas the lowest prevalences were generally reported in studies conducted in other countries, including China, Greece and Israel (2.2–5.6%).

Studies with high prevalences also reported doses in terms of frequency, duration of use, age at first use or cumulative doses. Frequency of use may vary from a few times per month to more than once a day, and a large proportion of use is more or less daily. Duration of use ranges up to more than 40 years. The cumulative exposure to talc by perineal dusting was over 10 000 days in 4% of the users in one study (Cook *et al.*, 1997). The use of talcum powder for feminine hygiene is acquired in young adulthood, since 80% of women who use body powder start before the age of 25 years (Harlow & Weiss, 1989).

The types of application also vary. Body powder can be applied perineally, on napkins or on underwear. Dusting of the perineum after bathing appears to be the most frequent single type of application, but simultaneous uses have also been reported. Alternatively, exposure may occur as a result of storing a diaphragm in body powder or contamination from the male partner who has used body powder. One study in the USA reported that the use of deodorant spray had a prevalence of 24% (Cook *et al.*, 1997).

In several of the studies in Table 1.18, the interviews on powder use occurred before 1988. Of these, all but one were conducted in the USA. Information on the composition

Table 1.16. Average mineralogical composition (%) of commercial products sold under the name of talc in North America

	Canada				Vermont			California		Texas	Montana	New York
	40 floated	10	30	70	30 floated	200	12 floated	10	307	326	20	140
Talc production (thousand tonnes)												
Mineral (%)												
Talc	92.5	64.5	60.5	55	90	52.5	94.5	54	80	94	8	25
Chlorite	3	11.5	10.5	7	7	9	1.5	5	1	4.5	85.5	
Dolomite	1	4	8	2	0.5	2	0.5	9	12.5	0.5	0.5	
Magnesite	1.5	17	18	34	2	33.5	0.5	16		T	T	
Serpentine			T									25
Quartz									T	T	T	
Mica	T	T							T	T	T	
Calcite	T											
Tremolite												44
Anthophyllite												5

From Ferret & Moreau (1990)

T, identified mineral that could not be measured by the methods of analysis used

Table 1.17. Average mineralogical composition (%) of commercial products sold under the name of talc in Europe

	Finland		Sweden	Norway	United Kingdom	France	Austria	Italy		Spain				
	75 floated	250 floated	15	50	17	320	80	20	40	46	17	33	20	28
Talc production (thousand tonnes)														
Mineral (%)														
Talc	93	88	64	55	54	59	51.5	51.5	86	51	47	89	80.5	53
Chlorite	3.5	8.5	16.5	11	9	39	42	43	9.5	19.5	22.5	6	12	18.5
Dolomite	0.5	T	11.5	2	2	1.5	1	2	1.5	12	14.5	2	1.5	6
Magnesite	1.5	2		29	30.5		1		0.5	10	14.5			18.5
Serpentine										T	T			
Quartz			T	T	T		T	T		T			T	
Mica			T				T	T					1.5	1.5
Calcite			T	T				T		T			0.5	T
Tremolite			T											

From Ferret & Moreau (1990)

T, identified mineral that could not be measured by the methods of analysis used.

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Table 1.18. Assessment of exposure to body powders in the perineal area by women

Location	No. of controls	Prevalence of ever use of talc	Type of perineal use of powder by women	Reference
Massachusetts, USA	215	28.4%	Exposure to talc by dusting	Cramer <i>et al.</i> (1982)
Washington DC, USA	171	1.8%	Body talc	Hartge <i>et al.</i> (1983)
California, USA	539	45.8%	Use of talcum powder	Whittemore <i>et al.</i> (1988)
United Kingdom	451	59.0%	Use of talc	Booth <i>et al.</i> (1989)
Washington, USA	158	40.5%	Exposure to powder (cornstarch, baby powder, talc, deodorizing powder); detailed information on type of powder used	Harlow & Weiss (1989)
Massachusetts, USA	239	39.3%	Exposure to baby powder, deodorizing or scented powder	Harlow <i>et al.</i> (1992)
China	224	2.2%	Dusting powder	Chen <i>et al.</i> (1992)
Maryland, USA	46	17.3%	Genital bath talc (also asked use on napkins or diaphragm)	Rosenblatt <i>et al.</i> (1992)
Athens, Greece	193	3.6%	Local application of talc	Tzonou <i>et al.</i> (1993)
Israel	408	5.6%	Use of talc	Shushan <i>et al.</i> (1996)
Toronto, Canada	564	35.6%	Regular application of talc	Chang & Risch (1997)
Washington, USA	422	39.3%	Dusting with cornstarch, talcum powder, baby or scented powder, and deodorizing spray	Cook <i>et al.</i> (1997)
New York, USA	50	26%	Use of talc	Eltabbakh <i>et al.</i> (1998)
Montreal, Canada	170	4.7%	Use of talc	Godard <i>et al.</i> (1998)
New England, USA	523	18.2%	Use of talc, baby or deodorizing powders or cornstarch	Cramer <i>et al.</i> (1999)
New York, USA	693	35%	Use of talc (on genital or thigh area and sanitary napkins)	Wong <i>et al.</i> (1999)
Delaware Valley, USA	1367	40%	Use of talc (on genital/rectal area and feet, sanitary napkins, underwear, diaphragm/cervical cap, male partner user)	Ness <i>et al.</i> (2000)
California, USA	1122	37.1%	Use of talcum powder	Mills <i>et al.</i> (2004)
USA	78 630 cohort	40.4%	Use of talc	Gertig <i>et al.</i> (2000)

of baby powder, body powder, facial powder and pharmaceutical talcum powder on the market in New York City before 1976 suggests that many of these products were impure and contained anthophyllite, carbonate, chlorite, chrysotile, phlogopite, pyrophyllite, quartz and tremolite (Cralley *et al.*, 1968; Rohl *et al.*, 1976). After 1976, these powders probably did not contain anthophyllite, chrysotile or tremolite but may have contained up to 10% of other minerals including carbonate, chlorite and quartz (Grexa & Parmentier, 1979). In 1994, baby talcum powder available in the USA typically contained 99% talc; body powder typically contained 65–70% talc and the remaining material was cornstarch, sodium bicarbonate and fragrance (Zazenski *et al.*, 1995).

(c) *Other uses of cosmetic talc*

Russell *et al.* (1979) and Aylott *et al.* (1979) reported exposure to respirable dust during the use of talcum powders on the face, body and babies. Russell *et al.* (1979) took 48 measurements during baby dusting operations and 44 measurements during the application of powders to adult bodies. Adult exposure was assessed during normal face/body powdering practices by placing cyclone samplers on shelves at an appropriate height or by positioning a cyclone attached to a headband near the nose (i.e. in the breathing zone). Exposure to respirable dust was $2.03 \pm 1.48 \text{ mg/m}^3$ during adult application and was estimated to be 0.19 mg/m^3 for babies. The estimated duration of the application was 1.23 minute for adults and 0.52 minute for babies.

Aylott *et al.* (1979) measured levels of exposure to respirable dust during the application of loose face powder (24 measurements), adult dusting powder (43 measurements) and baby dusting powder (32 measurements). In the study of baby dusting powder, a doll was used. The exposure to respirable dust during face powdering ranged from <0.1 to 1.7 mg/m^3 (duration, 10–25 seconds), that for adult dusting powder ranged from 0.2 to 3.3 mg/m^3 (duration, 15–80 seconds) and that for baby powders ranged from <0.1 to 0.9 mg/m^3 (duration, 15–60 seconds).

(d) *Other exposures*

Talc is used as a surface lubricant on the majority of condoms manufactured; contact with condoms may also represent a direct means of exposure of the female genital tract to talc (Kasper & Chandler, 1995).

Exposure to talc can also occur during surgical procedures when using powdered gloves. Talc particles were observed in the navels of small children, in the testes, on the vocal cords, in the urinary bladder tract and after removal of varicous veins (Ramelet, 1991; Simsek *et al.*, 1992). During breast implantations, it is possible that talc from surgical gloves can lead to unwanted encapsulation (Chandler & Kasper, 2003).

1.3.4 *Environmental exposure*

Talc is often detected as a common anthropogenic contaminant in suspended sediment, even in remote snowfields in the Alps; this has been ascribed to its emission

into the atmosphere by industrial and agricultural process (Hillier, 2001). Talc had also been identified in the sediment of the River Don in Scotland (United Kingdom), although no obvious industrial or agricultural sources of the talc were apparent (Hillier, 2001).

1.4 Regulations and guidelines

Occupational exposure regulations and guidelines for talc in several countries are presented in Table 1.19.

Table 1.19. Occupational exposure standards and guidelines for talc

Country or region	Concentration (mg/m ³)	Interpretation	Carcinogenicity
Australia	2.5	TWA	
Belgium	10 (I)	TWA	
	2	TWA	
China	3 (T)	TWA	
	4	STEL	
Canada			
Alberta	2 (R)	TWA	
British Columbia	2 (R)	TWA	
Ontario	2 fibres/cm ³ (R)	TWA; value is for particulate matter containing <1% crystalline silica	
Quebec	3 (R)	TWA (talc-containing no mineral or asbestos fibres)	
Czech Republic	10 (R)	TWA; fibres >5%	
	2 (R)	TWA; fibres ≤5%	
	10 (T)	TWA	
Denmark	0.3 fibres/cm ³	TWA; containing fibres	K
Finland	5	TWA	
Germany	(R)	MAK; without asbestos fibres	3B
Hong Kong	2 (R)	TWA	A4
Ireland	10 (I)	TWA	
	0.8 (R)	TWA	
Japan	0.5 (R)	TWA	
	2 (T)	TWA	
Malaysia	2 (R)	TWA	
Mexico	2 (R)	TWA	A4
Netherlands	1 (R)	TWA	
New Zealand	2 (R)	TWA	
Norway	2 (R)	TWA	
	6 (T)	TWA	

Table 1.19 (contd)

Country or region	Concentration (mg/m ³)	Interpretation	Carcinogenicity
Poland	1 (R) 4 (I)	TWA TWA	
South Africa	1 (R) 10 (I)	TWA TWA	
Spain	2 (R)	Ceiling; containing no asbestos fibres and <1% crystalline silica	
Switzerland	2	TWA	
United Kingdom	1 (R)	TWA	
USA			
ACGIH (TLV)	2 (R)	TWA; containing no asbestos and <1% crystalline silica	A4
NIOSH (REL)	2 (R)	TWA (10-h)	
OSHA (PEL)	~3 (20 mppcf)	TWA; containing <1% quartz	

From Direktoratet for Arbejdstilsynet (2002); Työsuojelusäädöksiä (2002); SUVA (2003); ACGIH® Worldwide (2005); Deutsche Forschungsgemeinschaft (2005); Health and Safety Executive (2005)

ACGIH, American Conference of Governmental Industrial Hygienists; I, inhalable dust; MAK, maximum concentration in the workplace; mppcf, millions of particles per cubic foot; NIOSH, National Institute for Occupational Safety and Health; OSHA, Occupational Safety and Health Administration; PEL, permissible exposure limit; R, respirable dust; REL, recommended exposure limit; T, total dust; STEL, short-term exposure limit; TWA, 8-h time-weighted average (unless otherwise specified)

^a 3B, substances for which in-vitro test, or animal studies have yielded evidence of carcinogenic effects that is not sufficient for classification of the substance in one of the other categories; K, included in the list of substances considered as carcinogenic; A4, not classifiable as a human carcinogen

The Food and Drug Administration regulates talc in the USA, and states that it is generally recognized as safe for use in colour additives in foods, drugs and cosmetics, and in paper, paper products, cotton and cotton fabrics that come into contact with food. The Food and Drug Administration also states that talc is present in over-the-counter astringent drug products (National Toxicology Program, 2000).

The Food Chemical Codex (2003) provides specifications for food-grade talc, including the statement that “talc derived from deposits that are known to contain associated asbestos is not food grade.” Under the voluntary guidelines initiated in 1976, the Cosmetic, Toiletry, and Fragrances Association stated that all cosmetic talc should contain at least 90% platy talc (hydrated magnesium silicate) that is free from detectable amounts (<0.5%) of fibrous, asbestos minerals (Gilbertson, 1995; Zazenski *et al.*, 1995; National Toxicology Program, 2000).

The current Occupational Safety and Health Administration (2005) permissible exposure level for non-asbestiform talc in the USA is $\sim 3 \text{ mg/m}^3$ (20 mppcf) measured as respirable dust. The current American Conference of Governmental Industrial Hygienists TLV-TWA is 2 mg/m^3 (15 mppcf), which also is the proposed Occupational Safety and Health Administration limit. Levels of exposure of workers may exceed three times the TLV-TWA for no more than 30 minute during the workday (National Toxicology Program, 2000).

1.5 References

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